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Attempt to detect weak asborption features with the NRAO interferometer line system.

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Introduction

The NRAO interferometer line system was used to search for 21 cm absorption in extragalactic sources. An earlier attempt with the same system was spoiled by system instabilities. The major cause of instability was thought to be the change in the shape of the IF passband with a change in delay. Accordingly the present program sought to avoid this by holding the delay constant and calibrating each scan on a source with a scan on a nearby calibrator at the same delay setting.

Holding the delay constant gives a delay error which produces a phase gradient across the passband. The analogue continuum correlaters are lost but the phase gradient across the spectrum can be corrected, provided the delay error ζ is small compared with the coherence time for a narrow band channel. (B Hz) ie $\zeta \ll 1/B$

For a 50 kHz channel width the delay error should be

$$\zeta \ll \frac{10^9}{5 \times 10^4}$$

$$\zeta \ll 2 \times 10^4 \text{ ns}$$

A delay error of 200 ns for example gives a phase gradient of 1/100 turn across an individual channel and 1 turn across a 4 MHz bandwidth. This is quite acceptable.

Observations and Reductions

The observations were taken in 20 minute scans followed by one or more calibrations at the same delay setting. The delay was manually entered from a look-up table and was arranged to be a compromise setting biased to the center of the scan on the source. The observed sources and calibrators are given in Table 1.

Table 1 Sources Observed

Source	Time (Hours)	Calibrators
FRED	13.3	3C48 same velocity 3C48 (- 750 km/s
3C275.1	9.3	3C279, 3C286
3C309.1	4.0	3C309-1 (+1000 km/s)

Programs have been added to the H-Line system to correct the line data for a delay error.

The steps in the reduction are as follows:

1) Correct for delay error.

2) Correct for passband shape (defined by one of the calibrators.

3) Align phases and integrate data.

Results and Discussion

The average peak-to-peak scatter in a 96 point frequency profile of an individual scan is given in Table 2.

Table 2 Scatter in Individual Scans

Source	Velocity (kn s^{-1})	Gain	p-p Scatter	σ
FRED	-150	x1	800	130
3C275.1	'750	x1	750	120
3C309.1	600	x10	180	300
3C48	-150	x10	400	600
3C48	-750	x10	Reference	
3C279	'750	x10	180	300
3C286	750	x10	Reference	
3C309.1REF	1600	x10	Reference	

The theoretical noise level is given by

$$\Delta Ta = \frac{T\ syst}{\sqrt{B\ t}}$$

Assuming T syst = 100 K, B = 50 kHz, and t = 20 mins with 0.1 °K per flux unit gives an rms noise of 125 mfu. in a 20 min. scan, only the weak sources FRED and 3C275.1 are in good agreement with this, however the observed scatter did not reduce as $\sqrt{t}$ upon integration. The observed rms scatter in four scans on FRED, 3C275.1 and 3C309-1 was 90, 100 and 220 mfu and the final observed rms values were respectively 60, 60, and 200 giving rms limits to any absorption feature of $\simeq$ 2.5% in all cases. This is a considerable improvement of the earlier attempt which give a 10% rms limit but the measurement is still limited by the calibration procedure rather than receiver noise.

a) 3C48 was used as a calibrator at the same and at offset frequencies. The offset frequency was used to define the shape of the passband. The observed rms scatter in the 96 point profile of the on-frequency observation was typically two or three times the theortical rms noise, in agreement with the observed scatter in 3C309-1 which was also calibrated by an off-frequency observation.

b) For 3C275-1 two calibrators were used at the same observing frequency. Using one as a reference the scatter in the other was again typically two or three times the rms noise.

Conclusions

Attempts to integrate weak absorption features using the interferometer line system have failed to reach the theoretical noise level due to fluctuations in the shape of the passband. These fluctuations are not completely calibrated out by holding the delay constant and observing calibrators at the same frequency or by calibrating with an off-frequency observation of the source.